Risk Factors for Agricultural Injury: A Case–Control Analysis of Iowa Farmers in the Agricultural Health Study

N. L. Sprince, C. Zwerling, C. F. Lynch, P. S. Whitten, K. Thu, N. Logsden–Sackett, L. F. Burmeister, D. P. Sandler, M. C. R. Alavanja

ABSTRACT. *The purpose of this case–control study nested in the Agricultural Health Study was to assess risk factors for agricultural injury among a large group of Iowa farmers. A questionnaire sent to 6,999 farmers identified 431 cases who had a farm work–related injury requiring medical advice/treatment in the previous year and 473 controls who had no injury in the previous year. We assessed several potential risk factors for injury. A multiple logistic regression analysis showed significant associations between farm work–related injury and weekly farming work hours (≥ 50 hours/week) (OR = 1.65; 95% CI = 1.23–2.21), the presence of large livestock (OR = 1.77; 95% CI = 1.24–2.51), education beyond high school (OR = 1.61; 95% CI = 1.21–2.12), regular medication use (OR = 1.44; 95% CI = 1.04–1.96), wearing a hearing aid (OR = 2.36; 95% CI = 1.07–5.20), and younger age. These results confirm the importance of risk factors identified in previous analytic studies and suggest directions for future research in preventive intervention strategies to reduce farm work–related injuries.*

Keywords. Agriculture, Farmers, Injury, Risk factors.

Farmers are at increased risk for work–related fatal and non–fatal injuries compared to most other occupations. The National Safety Council (NSC, 2000) reported occupational injury death rates for agriculture of 22.5 per 100,000 workers compared with 3.8 per 100,000 for all industries. According to the 1999 Census of Fatal Occupational Injuries data (U.S. Department of Labor, 2001), the major industry division with the highest occupational injury fatality rate was agriculture (including forestry and fishing). Substantial evidence also suggests increased rates of non–fatal injuries among farmers. For example, investigators found

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The authors are **Nancy L. Sprince,** MD, MPH, Department of Occupational and Environmental Health, **Craig Zwerling,** MD, PhD, MPH, Department of Occupational and Environmental Health, and Department of Epidemiology, **Charles F. Lynch,** MD, PhD, Department of Epidemiology, **Paul S. Whitten,** MA, Department of Occupational and Environmental Health, **Nyla Logsden–Sackett,** MS, Department of Epidemiology, and **Leon F. Burmeister,** PhD, Department of Biostatistics, University of Iowa College of Public Health, Iowa City, Iowa; and **Kendall Thu,** PhD, Department of Occupational and Environmental Health, University of Iowa College of Public Health, Iowa City, Iowa, and Department of Anthropology, Northern Illinois University, DeKalb, Illinois; **Dale P. Sandler,** PhD, National Institute of Environmental Health Sciences, Research Triangle Park, North Carolina; and **Michael C. R. Alavanja,** DrPH, National Cancer Institute, Rockville, Maryland. **Corresponding author:** Nancy L. Sprince, Department of Occupational and Environmental Health, 124 IREH–Oakdale Campus, University of Iowa College of Public Health, Iowa City, IA 52242–5000; phone: 319–335–4416; fax: 319–335–4225; e–mail: nancy–sprince@uiowa.edu.

that Iowa farmers were hospitalized for work–related injury at a rate three times higher than non–farmers (Fuortes et al., 1990). Non–fatal farm injury data derived from studies of dairy farmers in New York, dairy and beef farmers in Ontario, and diverse farm types in Alabama have shown a range of rates from 7.0 per 100 farmers per year (Ontario dairy and beef) to 16.6 per 100 farmers per year (N.Y. dairy) (Brison and Pickett, 1992; Pratt et al., 1992; Zhou and Roseman, 1994). A recent review by McCurdy and Carroll (2000) reported an overall farm injury risk of approximately 10% a year from a review of population–based studies.

Previous analytic studies addressing risk factors for farm injury have derived results based on relatively small numbers of injured farmers, ranging from about 30 to 155 (Brison and Pickett, 1992; Pratt et al., 1992; Zhou and Roseman, 1994; Lewis et al., 1998; Browning et al., 1998; Crawford et al, 1998; Hwang et al., 2001a; Park et al., 2001), limiting their ability to assess multiple risk factors concurrently in their multivariable models. The two largest of these previous studies (Pratt et al., 1992; Hwang et al., 2001a) both showed that being an owner/operator and working longer hours on the farm were significantly associated with farm injury.

The aim of this case–control study was to assess risk factors for farm work–related injury among a large group of injured Iowa farmers.

Materials and Methods

A case–control study nested in an ongoing prospective cohort study, the Agricultural Health Study (AHS) (Alavanja et al., 1996), was completed. Several aspects of this nested case–control methodology have been described previously in companion studies that assessed risk factors for high pesticide exposure events and machinery–related farm injury in the same cohort (Alavanja et al., 2001; Sprince et al., 2002).

Identification of Cases and Controls

We randomly chose 6,999 participants from a total of 30,009 certified Iowa private pesticide applicators in the AHS, almost all of whom are farm operators. We mailed screening questionnaires to them in November 1997. After two and a half weeks, we sent out a second mailing to non–respondents. Five weeks after the second mailing, we attempted to contact all non–respondents by telephone to administer the screening questionnaire. A total of 6,115 participants completed the screening questionnaire (response rate 87.4%). Of these, a total of 5,970 (97.6%) met the Census of Agriculture definition of "farmer" by responding "yes" to the question, "Did this farm have gross annual sales of agricultural goods of $1,000 or more in the past 12 months?"

Cases were defined as farmers who answered "yes" to both of the following questions: "During the past 12 months, were you injured seriously enough that you got medical advice or treatment?" (National Health Interview Survey, 1996) and "Was the injury in any way related to your farm operation (this includes activities such as farm–related transportation on roadways, or any other aspect of your farm, such as raising livestock for recreation or home use)?" (Gerberich et al., 1993).

Controls were randomly selected from among farmer respondents to the screening questionnaire who indicated that they had no injury requiring medical advice or treatment in the past 12 months. Those with a non farm–related injury (n = 133) were

ineligible to become cases or controls in this study. Controls were selected with the goal of equaling the number of cases.

Case–Control Interviews

All interviews were completed by trained interviewers using computer–assisted telephone interviewing (CATI). Based on responses to the questionnaire and to the eligibility questions in the case–control telephone interviews, 521 injury cases and 603 controls were eligible for the CATI interview. All eligible subjects received $10 if they completed the CATI interview. Subjects were called over a five–month period in 1998, from February 20 to July 30. After eight unsuccessful calling attempts, including attempts on evenings and weekends, a subject was considered a non–respondent. Of the 521 eligible cases, 431 (82.7%) were interviewed successfully. Of the 603 eligible and selected controls, 473 (78.4 %) were interviewed successfully. This report is based on responses from these case–control telephone interviews.

Questionnaire

Data on risk factors for injury and for injury outcomes were obtained at the same time from the same questionnaire. The time period of reference for the questions is indicated below. The questionnaire included sections in the following nine categories:

- Personal demographics.
- Work history and workload characteristics, including work on and off the farm, and help with farm work from spouse or other.
- Personal medical history.
- Depression, stress, and sleepiness.
- Alcohol consumption and cigarette smoking history.
- Degree of risk acceptance.
- Safety training history.
- Farm finances.
- Farm products.

For the outcome variable, farm work–related injury, the questionnaire included the following: injuries during the past 12 months, including description of body part(s) injured, type of injury, severity of injury, description of events, and sources associated with the injury.

The injury section questions on severity of injury included three from the National Health Interview Survey (NHIS, 1996) that assessed period of hospitalization, extent of missed work, and whether help is now needed for personal care. There was also a question about loss of consciousness as a result of the injury.

The medical condition questions were taken from the 1992 Health and Retirement Study questionnaire (HRS, 1992) and the 1994 National Health Interview Survey on Disability (NHIS–D, 1994). These included questions on current eyesight and hearing, use of glasses, contact lenses, hearing aids, and other disabling impairments or health conditions; and doctor (ever) diagnosed arthritis and rheumatism, depression, heart disease, and asthma. To assess medication usage, we included the following questions:

1. "In the past 12 months, have you had any medical condition for which you have taken medicine regularly (at least one day per week on most weeks or for three months or more in the past year)?"

1A. "What are these conditions? And, what are these medications?"

We included those who were taking medication only for an injury in the "no medication" group.

Questions on mood and stress included the Abbreviated 11–item CES–D Depression Scale (assessing symptoms over the last week) (Kohout et al., 1993; Radloff, 1977), the Four–item Perceived Stress Scale (assessing symptoms over the last month) (Cohen et al., 1983) with an added fifth question concerning changes in stress level over the last year, and the Epworth Sleepiness Scale (no time frame mentioned) (Johns, 1991).

The alcohol consumption questions assessed alcoholism using the CAGE questions ("Have you ever felt you should cut down on your drinking? Have people ever annoyed you by criticizing your drinking? Have you ever felt bad or guilty about drinking? Have you ever taken a drink first thing in the morning to steady your nerves or get rid of a hangover?") (Ewing, 1984), as well as lifetime and current drinking status, and usual amount of alcohol consumed. Each CAGE question response was "yes" or "no," where "yes" was the response associated with greater likelihood of alcoholism. We considered three or four "yes" responses to be a high CAGE score. The cigarette–smoking questions (ever smoked versus currently smoke) were from the Third National Health and Nutrition Examination Survey (NHANES, 1994).

We assessed the degree of risk acceptance with five agree/disagree items from Harrell (no specific time frame mentioned) (Harrell, 1995):

1. "Farming is more dangerous than jobs in industry or manufacturing."
2. "Accidents are just one of the occupational hazards of farming that must be accepted if you are going to be in the business."
3. "Compared to other farmers I am very conscientious about avoiding accidents."
4. "During a normal work week, it's common for me, while doing farm work, to experience a number of 'close calls' that under different circumstances might have resulted in personal injury or property loss."
5. "To make a profit, most farmers take risks that might endanger their health."

In our analysis, an answer of "disagree" was counted as a zero for questions 2, 4, and 5, and an answer of "agree" was tallied as a one. Responses of "agree" were counted as zeroes for questions 1 and 3, while "disagree" responses were tallied as ones. A cumulative score of 0 to 2 was considered "risk averse," while a score of 3 to 5 was considered "risk accepting."

The safety training section included questions on source, date, and duration of training in any organized farm safety program or course. These questions did not specifically address injury prevention training.

The farm finances and products section included questions on the number of acres farmed (over the past 12 months), current farm debt as a percent of farm assets, types of crops or livestock raised on the farm (over the past 12 months), and the farmer's self–assessment of the current financial condition of the farm.

This study was reviewed and approved by the Institutional Review Board on human subjects at the University of Iowa.

Data Analysis

We coded all injuries according to nature of injury, part of body affected, source of injury, and event /exposure related to injury using the Bureau of Labor Statistics'

1992 *Occupational Injury and Illness Classification Manual* (U.S. Department of Labor, 1992). After one investigator (Thu) coded all the injuries, two additional investigators (Sprince and Zwerling) reviewed the coding. The original coding was revised only if both secondary coders agreed on the change in coding.

For stress, depression, and sleepiness, we scored the responses according to standard scales and dichotomized the scales into high and low exposure categories. These were defined as follows: stress was considered to be high if the stress score was greater than 8 on a scale of 5 to 15; depression scores were considered to be high if they were greater than 16 on a scale of 11 to 33; and sleepiness was considered to be high if the sleepiness score was greater than 15 on a scale of 8 to 32. Continuous variables, aside from age, were dichotomized at the median for the analyses.

Demographic characteristics of the cases and controls were compared using Student's t–test for continuous variables and chi–square analysis for dichotomous variables. We used questionnaire responses to the nine risk factor categories described above as the independent variables of interest. We performed bivariate analyses to assess the association between each independent variable and the dependent variable, farm work–related injury in the previous year. To determine the strength of association between these independent variables and farm work–related injury, we calculated the Mantel–Haenszel chi–square (Mantel and Haenszel, 1959). The Higgins and Koch (1977) method for variable selection was used to construct a logistic regression model. For this procedure, we included only those independent variables likely to precede an injury in the past year and not those that could also result from injury (depression, stress, and risk acceptance). To assess each independent variable's relationship with farm work–related injury, we calculated Mantel–Haenszel chi–squares (divided by one degree of freedom). We then selected the variable with the largest chi–square, significant at $p \leq 0.05$, controlled for that variable, and re–analyzed the remaining variables. This procedure was repeated until no further independent variables were significant at $p \leq 0.05$.

After the variable selection process described above, we entered the chosen variables into a multivariable logistic regression model using forward selection. We compared results of that model with a backward elimination model and found no differences in the variables remaining in the final model. We assessed the goodness–of–fit of the resulting model (Hosmer and Lemeshow, 1989, pp. 140–145). The dependent variable used was case versus control, as defined above. After construction of this base model, we added all independent variables that were not selected by the Higgins and Koch method (1977) to the model, one by one, to assess the strength of association of each remaining independent variable with farm work–related injury, after adjustment for the independent variables in the base model. The unit for analysis was the individual injured farmer, regardless of the number of injuries the farmer reported.

Results

There were 510 injuries reported among the 431 cases. Cases were younger than controls (47.5±12.0 versus 50.0 ±11.7; $p = 0.002$). Of the 431 injured subjects, 377 reported a single injury over the past year, while the remaining subjects reported two or more injuries over the past year. Fifty–two subjects required hospitalization for their injury. Table 1 summarizes the nature of injury, part of body affected, source of injury, and event causing the injury. Strains/sprains/tears and cuts/lacerations were the most frequently reported injuries. Fingers, hands, and back were the most

Table 1. Characteristics of the 510 injuries among 431 Iowa farmers who reported a farm work–related injury in the past 12 months.

Characteristic	No. of Injuries	% of Total Injuries
Nature of injury		
Sprains, strains, tears	104	20.4
Cuts, lacerations	104	20.4
Fractures	74	14.5
Dislocations	46	9.0
Bruises, contusions	46	9.0
Other[a] or unspecified	136	26.7
Part of body injured		
Finger, fingernail, or hand	119	23.3
Lumbar region or back	75	14.7
Eye	40	7.8
Shoulder	37	7.3
Knee	31	6.1
Other[a] or unspecified	208	40.8
Source of injury		
Machinery	228	44.7
Animal	131	25.7
Other[a] or unspecified	151	29.6
Event causing injury		
Falls	85	16.7
Struck by slipping or flying object	74	14.5
Assault by animal	63	12.3
Overexertion in lifting	44	8.6
Struck by falling object	33	6.5
Struck against stationary object	29	5.7
Other[a] or unspecified	182	35.7

[a] All remaining categories, each of which accounted for fewer than 5% of injuries, were included within "other."

frequently reported parts of the body affected. Animals and machines stood out as the most important sources of farm injuries.

Factors significantly associated with farm work–related injury (adjusting for age) included education beyond high school, working at least 50 hours per week on the farm, working at least 50 weeks per year on the farm, having help with farm work from people other than a spouse, having large livestock on the farm, wearing a hearing aid, having difficulty hearing normal conversation even with a hearing aid, doctor–diagnosed arthritis, doctor–diagnosed depression, high depression and stress scores, and higher CAGE scores indicating problems with alcohol (table 2). Working part–time on the farm and working off the farm for at least 12 weeks in the past year were protective.

The results of multiple logistic regression analysis (table 3) showed that working at least 50 hours per week on the farm, education beyond high school, younger age, having large livestock on the farm, taking medications, and wearing a hearing aid were significantly associated with injury. A Hosmer and Lemeshow goodness–of–fit test (1989, pp. 140–145) resulted in a $p = 0.94$, indicating an adequate fit for this model.

Table 2. Bivariate associations of risk factors with farm work–related injuries.

Variable[a]	Exposed		Not Exposed		Odds Ratio[b]	95% CI[b]
	Cases	Controls	Cases	Controls		
Demographic features						
Male gender	425	465	6	8	1.27	(0.40–4.02)
Education more than high school	233	206	198	267	1.51	(1.16–1.97)
Not married	52	47	379	426	1.14	(0.75–1.75)
Principal operator	380	414	51	59	1.24	(0.82–1.88)
Lives on farm	399	428	31	45	1.38	(0.85–2.25)
Had safety training prior to any injury	155	174	274	298	0.92	(0.70–1.22)
Farm work experience ≤ 25 years	234	206	197	267	1.30	(0.94–1.79)
Personal habits						
Current smoker	37	48	392	425	0.85	(0.54–1.33)
Ex–smoker	129	126	300	347	1.27	(0.95–1.71)
Drinks alcohol currently	336	357	95	116	1.08	(0.79–1.48)
Has two or more drinks per day	77	86	258	271	0.90	(0.63–1.28)
CAGE score high	20	10	380	415	2.10	(1.01–4.40)
Farming factors						
Farm size small (≤ 500 acres)	183	229	236	232	0.80	(0.61–1.05)
Large livestock on farm	356	342	66	123	1.84	(1.32–2.58)
Debt/asset ratio ≥ 10%	270	268	142	183	1.24	(0.93–1.64)
Self–reported financial condition poor/fair	87	95	333	369	1.02	(0.73–1.41)
Workload factors						
Farmer worked 50 or more weeks on farm in past year	353	355	78	117	1.44	(1.04–1.99)
Farmer worked 50 or more hours per week on farm in past year	289	252	141	214	1.69	(1.29–2.22)
Spouse helped 8 or more weeks on farm in past year	226	233	205	240	1.13	(0.87–1.47)
Spouse helped 2 or more hours per week on farm in past year	226	230	203	238	1.15	(0.89–1.50)
Others helped 12 or more weeks on farm in past year	235	213	195	257	1.45	(1.11–1.88)
Others helped 24 or more hours per week on farm in past year	210	234	216	232	0.97	(0.74–1.26)
Farmer worked part–time on farm in past year	24	52	407	421	0.49	(0.30–0.79)
Farmer had job off farm in past year	122	157	308	314	0.78	(0.58–1.03)
Farmer worked 12 or more weeks off farm in past year	72	115	358	355	0.62	(0.45–0.86)
Medical conditions						
Wears eyeglasses	261	317	170	156	0.88	(0.66–1.18)
Self–reported vision poor/fair	18	31	413	442	0.67	(0.37–1.21)
Wears hearing aid	19	11	412	462	2.23	(1.06–4.67)
Self–reported hearing poor/fair	85	95	345	377	1.05	(0.76–1.46)
Difficulty hearing normal conversation with hearing aid	122	106	309	365	1.42	(1.05–1.92)
Doctor–diagnosed arthritis or rheumatism	86	74	343	395	1.50	(1.06–2.13)

Variable[a]	Exposed		Not Exposed		Odds Ratio[b]	95% CI[b]
	Cases	Controls	Cases	Controls		
Doctor–diagnosed depression	34	23	393	448	1.82	(1.06–3.13)
Depression score high	54	38	370	430	1.65	(1.06–2.56)
Doctor–diagnosed heart disease	34	49	397	423	0.84	(0.53–1.34)
Doctor–diagnosed asthma	28	20	403	452	1.63	(0.90–2.96)
Pre–existing disability	85	82	331	390	1.29	(0.92–1.80)
Sleepiness score high	219	216	211	257	1.27	(0.98–1.66)
Takes medication regularly	147	157	284	316	1.21	(0.91–1.62)
Risk acceptance and stress						
Risk acceptance score high	61	72	337	311	0.94	(0.65–1.37)
Stress score high	108	78	323	395	1.67	(1.21–2.31)

[a] Variables in *italic* are associated with injury in bivariate analysis, and their age–adjusted 95% confidence interval does not include 1.00.
[b] Age–adjusted odds ratio and 95% confidence intervals.

Table 3. Multiple logistic regression analysis of risk factors for farm work–related injuries.

Independent Variable	Odds Ratio[a]	95% CI
Farmer worked ≥50 hours per week on farm in past year	1.65	(1.23–2.21)
Large livestock on farm	1.77	(1.24–2.51)
Education more than high school	1.61	(1.21–2.12)
Age: 22–39	1.00	Reference category
40–64	0.60	(0.42–0.83)
≥65	0.60	(0.35–1.02)
Takes medication regularly	1.44	(1.04–1.96)
Wears hearing aid	2.36	(1.07–5.20)

[a] Each odds ratio has been adjusted for all other independent variables in the table.

When we examined the other potential risk factors that had not been selected through the Higgins and Koch method (1977), we found that both working part–time on the farm (OR = 0.57; 95% CI = 0.32–0.98) and working off the farm for at least 12 weeks in the past year (OR = 0.69; 95% CI = 0.48–0.99) were protective from farm injury.

Discussion

This study identified risk factors associated with farm work–related injury occurring over a 12–month period in a large group of Iowa farmers. Characteristics of younger age, education beyond high school, long work weeks on the farm (≥50 hours per week), having large livestock on the farm, taking medication, and wearing a hearing aid were associated with increased risk of farm work–related injury.

In a recent review of the literature, McCurdy and Carroll (2000) pointed out several population–based morbidity studies showing increased rates of agricultural injury at the age extremes (i.e., younger than 19 or older than 65). U.S. mortality data suggest that farm fatalities increase in the age group older than 64 (Myers and Hand, 1995). In contrast to our finding of increasing risk among younger farmers, Brison and Pickett (1992) found in an unadjusted analysis that relative risk of injury increased with age. However, age was correlated with years of work on the farm. The latter was used in their final model because it accounted for a larger amount of variability. As in our study, Zhou and Roseman (1994) and Hwang et al. (2001a) found an increased

risk of injury among younger farmers. Pratt et al. (1992) found that unadjusted injury rates were highest in the 31–40 and 51–60 age groups, but neither age nor gender was significantly associated with injury in a model that included type of worker (owner versus non–owner). Crawford et al. (1998) found the highest odds of farm work–related injury among farmers younger than age 30.

Studies of other occupations have suggested that younger, less experienced workers have increased risk for injury. Lack of experience, poorer financial condition, and risk–taking behaviors are all possible explanations for this association. When the variables for financial condition (subject's self–report of farm's financial condition) and risk acceptance were entered separately into the base model, we found no change in the significant association between younger age and injury. Neither risk acceptance nor financial condition was significantly related to injury in these models. Although we cannot assess whether the degree of risk acceptance preceded or was a consequence of injury, these results suggest indirectly that inexperience related to younger age may be the more important factor involved in increased injury risk. Another possible explanation for our finding is that younger farmers are better able to recall and report injuries than older farmers.

Several other studies have addressed associations between education and farm work–related injury. In a population–based study of Iowa farmers, Lewis et al. (1998) reported that farmers with more education had twice the risk for farm work–related injury in univariate analysis. However, this variable did not remain in the multivariable model controlling for other risk factors. Zhou and Roseman (1994) described a significant association between education level and injury risk. Lyman et al. (1999) reported that farm owner/operators with post–high school education were at increased risk for injury at some time in their farming careers. It is possible that higher education increases the likelihood of recalling and reporting farm work–related injuries. Although it is possible that younger farmers are more highly educated, our results show that younger age and higher education are both significantly associated with farm work–related injury (table 3).

Our results are consistent with those of other studies that showed a relationship between injury and large livestock on the farm (Brison and Pickett, 1992; Browning et al., 1998; Nordstrom et al., 1995). A study of dairy farmers in New York (Pratt et al., 1992) showed a high annual injury rate among dairy farmers (16.6%), although the major causes were about equally distributed between livestock (32%) and machinery (35%). These other studies have been carried out among farming operations involved with beef and dairy cattle, not hogs. A prospective cohort study of Iowa farmers (Park et al., 2001) reported a significant association between hours worked with livestock and injury risk. Since Iowa is the leading hog producer in the U.S., we postulated that hogs would be significantly associated with farm injury. When we evaluated the relative strengths of the association with injury of cattle versus hogs, we found that farmers who produced only hogs had similarly elevated odds for farm injury (OR = 1.70; 95% CI = 1.08–2.69) compared to those farmers who produced cattle only (OR = 1.69; 95% CI = 1.12–2.55).

Some studies have suggested an association between use of specific classes of medications and risk of occupational injury (Gilmore et al., 1996; Pickett et al., 1996). In their study of 117 beef and dairy farms, Brison and Pickett (1992) found that farm owners who used prescription medications were 2.6 times as likely to have a farm work–related injury compared with those who did not use these medications. However, this result did not reach statistical significance ($p = 0.07$). In our study, farmers who took medications for medical conditions (other than injury) had 1.44 times the odds of having a farm work–related injury. We were not able to perform

analysis by specific medication subgroup because of small subgroup sizes. There are several possible explanations for the observed association between medications and injury. One possibility is that injuries are increased because of medication side effects that may alter alertness or cause impaired judgment. Another possible explanation is that the underlying conditions requiring medications may impair physical or mental abilities. Medications may be prescribed to treat underlying stress or stress–related medical conditions. Studies are needed to further evaluate the medication–injury associations.

In our study, the strongest association with farm work–related injury was seen in farmers wearing a hearing aid. In a previous series of studies that assessed associations between disabilities and occupational injury in large, nationally representative working, non–farming populations (Zwerling et al., 1996, 1997, 1998a, 1998b), we consistently found that impaired hearing significantly increased the odds of occupational injury. However, we did not find such an association when we examined nationally representative working farmers as a subgroup (Zwerling et al., 1995), but the farming group was small (237 farmers with 15 total injuries), limiting the power of that analysis. In a study involving 998 Kentucky farmers older than 54 who sustained 98 agricultural injuries during the previous year, Browning et al. (1998) found a 60% increased odds of farm work–related injury among those who reported difficulty hearing, although the result did not reach statistical significance ($p = 0.08$). Our results support those of Hwang et al. (2001a), who showed a significant association between hearing loss and farm injury among New York farmers.

The explanation for an association between hearing and farm injury is not clear. A possible explanation could be limitation in hearing sounds that may warn of impending exposures. As pointed out in a recent study (Hwang et al., 2001b), lifetime exposure to noisy farm equipment was associated with self–reported hearing loss among New York farmers. Their finding raises the possibility in our study that both wearing a hearing aid and injury risk may be related through exposure to the noise of farm machinery. We believe that our finding of a strong association between wearing a hearing aid and farm injury should be interpreted with caution, since we were not able to assess several important factors, such as exposure to the noise of farm machinery and the noise of farm animals. The findings from our study and others' studies should lead to future research addressing the underlying reasons for this association as well as appropriate preventive interventions.

Workload characteristics were associated with farm work–related injury in our study, confirming the results of others who found associations between injury and hours worked (Pratt et al., 1992) or percent of working time spent farming (Brison and Pickett, 1992; Zhou and Roseman, 1994). Over the last ten years, a higher proportion of farmers have engaged in off–farm work while continuing their farm operations (U.S. Department of Agriculture, 1999). We postulated that the effect of off–farm work may lead to increased risk for injury, perhaps from the added stress of running a farm while working another job. However, our results did not support this hypothesis. This changing pattern of work organization for farmers may have other effects on their workplace health and safety. One of the National Occupational Research Agenda priority areas for research in occupational health and safety is work organization in a changing economy (NIOSH, 2001). For those reasons, we believe that changes in work organization for farmers should remain an active area for research in occupational health and safety.

In our study, the results of bivariate analysis suggested associations between injury and both stress and depression. However, there is uncertainty about whether stress and depression preceded the injury or resulted from the injury, given our study design.

Although previous studies have shown moderate reproducibility of these scales over time (Radloff, 1977; Cohen et al., 1983), they are sensitive to intervening life events, which could include physical injury. Prospective study designs would be more useful in assessing these associations.

Our study agrees with a previous population–based study of Iowa farmers that showed no protective effect of prior safety training on prevention of farm work–related injury (Lewis et al., 1998). Our data do not provide information about whether the safety training focused on farm work–related injury prevention.

Interpretation of these results should take into account the study limitations. Recall bias is a potential limitation, since injured participants may have different patterns for recall and reporting of risk factors, compared with uninjured controls. Another possible source of bias is the fact that all injuries were self–reported. Validation of injury self–report with record linkage in physicians' offices or hospitals was not part of our study design. In addition, because of small numbers of women farmers, our study cannot be used to assess gender differences in risk factors for farm work–related injury. Generalizability of these results to all U.S. farmers may be limited because of regional differences in farm commodities. For example, Iowa's major agricultural products, namely corn, soybeans, hogs, pigs, cattle, and calves, differ from those in other regions of the U.S. (U.S. Department of Agriculture, 1999).

Generalizability of these results to all Iowa farmers is another question of interest. All cases and controls in this study were drawn from participants in the Agricultural Health Study who were enrolled in that study between 1993 and 1997. In comparison to Iowa farmers characterized in the Censuses of Agriculture for 1992 and 1997 (U.S. Department of Agriculture, 1999; U.S. Department of Commerce, 1992), participants in the Agricultural Health Study are on average about five years younger, are more likely to work on larger farms and to apply pesticides, are somewhat more likely to raise beef cattle and hogs, and more frequently grow corn, soybeans, hay, and oats. These differences should be taken into account in planning preventive actions or further research based on these results. Because this was a case–control study, there are some questions about the temporal relationship between injury and some risk factors.

The study has several strengths. Since we collected data on a large number of injured Iowa farmers, we were able to examine multiple risk factors for injury concurrently and to assess associations suggested by smaller studies. Because of the large sample size, we were also able to investigate possible explanations for observed associations, such as the effects of risk acceptance and financial condition on younger farmers' injury risk. The high participation rate helped ensure adequate representation of the screened participants.

Conclusion

We have identified several risk factors for farm work–related injury, including younger age, large livestock including cattle and hogs, long work weeks, wearing a hearing aid, and medication use. These results have confirmed the importance of risk factors identified in previous analytic studies. These findings suggest directions for future research in preventive intervention strategies to reduce farm work–related injuries.

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